Temperature, Internal Energy and Heat

Big Idea - everything is made of atoms of molecules in motion.

Temperature is the average kinetic energy of the particles (atoms and molecules) that make up stuff.

For an ideal gas,
Boltzmann's constant
$k_B = 1.38 \times 10^{-23} J/K$

$\overline{E}_k = 3/2\ k_B T = 3/2\ (R/N_A)\ T$ the average kinetic energy of the particle composing an ideal gas.

T is temperature in Kelvin
convert from Kelvin to Celsius, subtract 273.15º
Celsius scale is based on freezing water at 0 Celsius and boiling water at 100ºC at 1 atm = 101.3kPa

Kelvin is also based on water for the change, so a change in Kelvin = change in Celsius
but zero kelvin is when the kinetic energy of the particles = 0 (stop)
absolute zero - you can't move slower than not moving

eg. The temperature in the classroom is 20.0ºC. What is the

a) temperature in Kelvin

20.0+273.15=293.15 =293.2K

a) the average kinetic energy of the air molecules?

E_k=3/2 k_BT

= (3/2)x(1.38E-23)x(293.15)=

= 6.07 x 10^{-21}J

a) the average speed of the air molecules (assume air is N_2, molecular mass of 28g/6.02x10^{23})

Ek=1/2mv^2 v =

sqrt(2x(6.07E-21)/(0.028/6.02E23))=

510.8913778877074

511m/s

a) what is your favourite colour?

Green

The sum of all the molecular collisions causes air pressure.

P=F/A force/area, in Pascal, Pa=N/m^2

F=Δp/Δt the change in momentum of the air particles produce the force

Ideal Gas Law:

PV = nRT

P is pressure, in Pa (if V in m^3) or in kPa (if V in Litres)
V is Volume in m^3 or L
R= 8.31 J/Kmol
$N/m^2 \times m^3 = Nm = J$
or kPa x L = J $1000 N/m^2 \times 1/1000\ m^3 = J$
n number of moles of the gas = number of molecules/avagadro's number 6.02×10^{23} 1/mol
T is temperature in Kelvin

If a gas is compressed or expanded, it does work.
W= Fs
P=F/A
W=PAs = PΔV
W=PΔV
area under a P-V graph - for reversible heat engines - it is the area inside the P-V graph

eg. A 2.0 L cylinder of Nitrogen at 20.0ºC and 1.000 atmosphere (101.3kPa) is expanded while the pressure decreases linearly to half an atmosphere to 4.0L.

a) How many moles of nitrogen are in the cylinder?

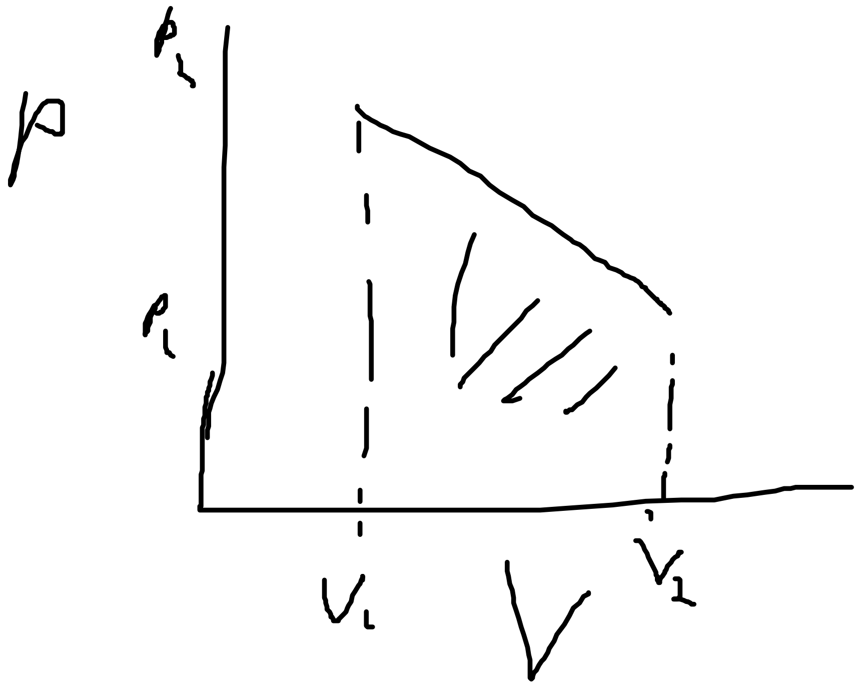
n = PV/RT = 101.3kPax2.0 L/8.31J/Kmol 293.15 = 0.083 mol

b) What is the new temperature of the gas?

T= same 20.0ºC (half the pressure but double

the volume, PV)

c) How much work was done by the gas?
W= area under P-V graph



area= 1/2 (P1+P2)(V2-V1) = 1/2 (101.3+ 50.65)(4.0L-2.0L) = 152J

https://phet.colorado.edu/en/simulation/legacy/gas-properties

Homework - Play with applet
P466 - 468 problems 41, 53, 75, 77, 83, 87